understanding of the molecular mechanisms that generate and maintain phosphatidylserine asymmetry is still in its infancy. The recent identification of phosphatidylserine-specific receptors and the development of genetically encoded biosensors to detect phosphatidylserine in live cells will accelerate discovery in this field.

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CLIMATE CHANGE

Carbon Crucible

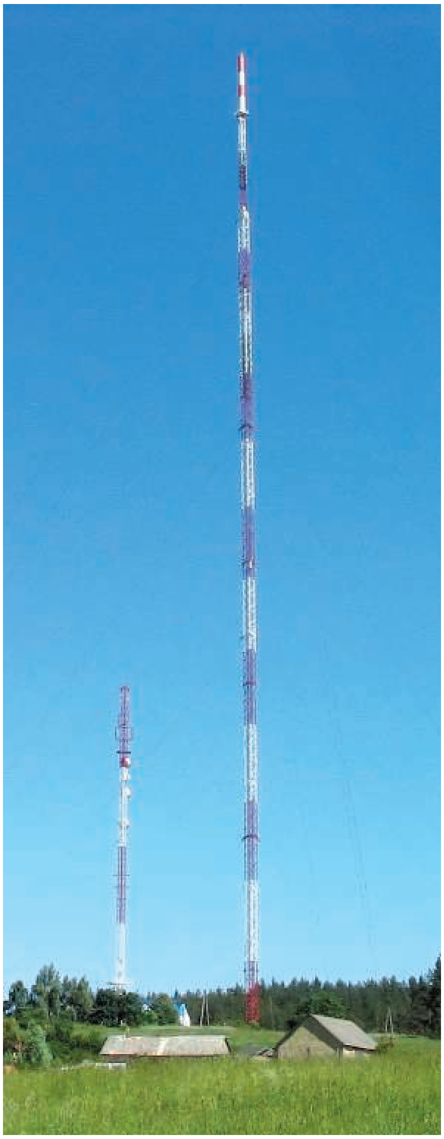
What are the data and modeling requirements for gauging the success of mitigation strategies in reducing greenhouse gas emissions?

Melinda Marquis[1,2*] and Pieter Tans[2]

Atmospheric measurements show that the carbon dioxide (CO_2) concentration in the atmosphere is currently ~385 parts per million (ppm) and rising fast. But this value is a global average that tells us nothing about the regional distribution of greenhouse gas emissions. As the world embraces myriad mitigation strategies, it must gauge which strategies work and which do not. Gaining such understanding will require a greenhouse gas monitoring system with enough accuracy and precision to quantify objectively the progress in reducing emissions, including regional efforts like those in California, New England, and elsewhere.

The current sparse network of observation sites across North America and elsewhere allows us to resolve annual continental fluxes of CO_2. But successful mitigation requires fluxes to be resolved within much smaller regions—on the order of the size of a European country such as France or a U.S. state such as Kansas. Current ground-based measurement technology can provide the required precision, but the number of measurements is insufficient. Data are collected by numerous agencies around the world, yet an integrated system is needed that uses all available data and ensures rigorous quality control for data collection and data analysis.

A powerful way to use all these data is in a data assimilation system, which combines diverse (and often sparse or incomplete) data and models into a unified description of a physical/biogeochemical system consistent with observations. Components of such systems include models of terrestrial photosynthesis (removal of CO_2, called a sink) and respiration (a source of CO_2), models of ecosystem emissions and uptake of other greenhouse gases, models of gas exchange between atmosphere and oceans, and models of gas emissions from wildfires—all grounded in observations.



The advantages of height. Atmospheric measurements are made on the tall tower (300 m). The tower, located near Bialystok in eastern Poland, is part of the CarboEurope tall tower network. Similar networks exist in North America and more sparsely in other parts of the world.

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The current grid scale for such assimilation systems—such as CarbonTracker, the first data assimilation system to provide CO_2 flux estimates (*1*, *2*)—is limited to ~100 km or larger, primarily due to computer resource limitations. Currently sparse atmospheric greenhouse gas data force us to make the assumption that source variations are coherent over very large spatial scales. More observation sites would make the systems more strongly data-driven. Data assimilation systems also need more refined estimates of fossil fuel emissions, and better process understanding to provide greater detail in emission patterns. Lastly, better models of atmospheric transport will increase the resolution and decrease biases of the data assimilation system. Our ability to distinguish between distant and nearby sources and sinks is limited by how accurately transport models reflect details of the terrain, winds, and atmospheric mixing near the observation sites.

National emissions inventories (which are required by the U.N. Framework Convention on Climate Change) are key data sets for assimilation systems. Inventories are mostly based on economic statistics, which are used to estimate how much of each greenhouse gas enters or leaves the atmosphere (*3*). They are reasonably accurate for CO_2 from fossil fuels (within ~10%) in many developed countries but less so in developing countries and on regional scales. Inventory emission estimates are much less reliable for other CO_2 sources, such as deforestation, and for other major greenhouse gases; for example, the contributions of natural wetlands, rice farming, and cattle to the global methane

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burden are each uncertain to ~30% (*4*). When comparing emission inventories with atmospheric data, substantial errors in the former have been documented (*5*).

The greatest hurdle to rapid progress, however, is the sparseness of atmospheric data. Current measurements include air sampled in flasks, in situ continuous measurements on tall transmitter towers (see the figure), and data from aircraft. Measurements from tall towers are particularly useful. The trace gas concentration observed on a tall tower provides information from a radius of several hundred kilometers. To provide meaningful observation-driven quantification of greenhouse gas sources, the number of sites must be increased from today's ~100 to ~1000, distributed in a suitable global network, and a substantial proportion of these should be tall towers. This could be achieved by placing greenhouse gas measurement instruments on existing communication towers around the world. Vertical-profile observations from aircraft are essential to improve simulation of air exchange between the boundary layer at Earth's surface and the free troposphere above in atmospheric transport models.

Satellite-based instruments can also provide information about CO_2 concentration in the atmosphere, but no current satellite-borne instrument comes close to providing the accuracy, precision, and continuity required to determine regional CO_2 concentrations and local fluxes. Future satellites, including the Orbiting Carbon Observatory (OCO) (*6*) and the Greenhouse Gases Observing Satellite (GOSAT) (*7*), are expected to provide more accurate CO_2 measurements than do today's satellites.

A key component of an improved monitoring system will be simultaneous observations of isotopic ratios and other chemical species characteristic of different source processes. For example, ^{14}C is absent from fossil fuels; recent emissions of fossil-fuel–derived CO_2 reduce the $^{14}C/C$ ratio of CO_2, which can be accurately measured in a few liters of ambient air.

The accuracy requirements for all of these measurements are challenging. For instance, fossil fuel burning in the U.S. adds, on average, less than 1 ppm to the background level of 385 ppm each year. This helps to explain the demanding goal for accuracy of 0.1 ppm for CO_2, and similar goals for CH_4 and N_2O, set by the Global Atmospheric Watch Programme (*8*) of the World Meteorological Organization (WMO). Meeting this goal will require consistent and rigorous application of quality-control and quality-assurance procedures to measurements, analysis, and data handling. Currently, participants in the WMO network can achieve an accuracy of 0.2 ppm, too imprecise by a factor of 2.

Satellite measurements are indispensable in achieving global coverage, but sensor drift (due to temperature effects, aging electronic sources, and the like) and potential artifacts with CO_2 retrieval will be an enduring concern for developing long-term records. The current mission specifications for the OCO satellite require a precision of 1 to 2 ppm, which would be an enormous improvement over that of previous satellites, but may still be too imprecise for regional flux estimates. Satellite retrievals will need continuing validation by comparison to optical absorption spectra that provide CO_2 averaged from the top of the atmosphere to the Earth's surface, and to in situ measurements; the latter will in turn need ongoing duplication by independent methods and laboratories.

Achieving the monitoring system described above will require a global increase in the number of observation sites by roughly a factor of 10, requiring the political will to implement these sites. Further, the success of such a system will require an international framework and support at national levels worldwide, as part of the Global Earth Observation System of Systems (GEOSS). The challenge of creating such a system is a defining test, a critical crucible.

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CELL BIOLOGY

RNA Metabolism and Oncogenesis

Regulating the production of RNAs involved in protein synthesis can induce the transformation of cells to an oncogenic state.

Deborah L. Johnson and Sandra A. S. Johnson

The transformation of cells to a malignant state involves the deregulation of protein synthesis. Transfer RNAs (tRNAs) and ribosomal RNAs (rRNAs) are essential components of the cell's protein synthesis machinery. A hallmark of neoplastic transformation is the enhanced accumulation of rRNAs and tRNAs and the increased size of the nucleolus, the site for rRNA synthesis in the nucleus. Underlying these changes is the increased activity of RNA polymerase III, which synthesizes tRNAs, 5*S* rRNAs, and other RNAs that play essential roles in protein synthesis. Although tumor suppressor proteins and oncogenic proteins regulate RNA polymerase III activity (*1–5*), a causal connection between rRNA and tRNA metabolism and malignancy has been elusive. Now, a study by Marshall *et al.* (*6*) provides compelling evidence that enhanced activity of this polymerase is indeed essential for cellular transformation.

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The transcription of eukaryotic genes requires a set of proteins that specify the placement of RNA polymerase for proper initiation of RNA synthesis to occur. These transcription initiation factors have long been viewed as "housekeeping" proteins. That their activity may be regulated, and that such regulation could be responsible for differential gene expression, once seemed implausible. But, for example, the transcription factor complex TFIIIB, which specifies RNA polymerase III transcription, is indeed controlled by various tumor suppressors and oncogenic proteins (see the figure), suggesting that changes in the complex's activity are associated with malignancy. Because transcription factor complexes are multiprotein structures, their regulation can involve modifications of a single component that can affect interactions among multiple proteins in the complex.

TFIIIB consists of three proteins: the RNA polymerase III–specific components Brf1 and